



Research Department Report

THE AIRBORNE SOUND INSULATIONS OF METAL-FRAMED PARTITIONS

G. D. Plumb, M.A. (Cantab.)

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Summary

The sound insulation performances of several lightweight, metal-framed partitions were measured in Research Department's Transmission Suite. The aim was to produce a design for a new type of partition which was cheaper than the 'Camden', which is currently used throughout the BBC, while maintaining a comparable sound insulation.

As a result of the studies, a partition is recommended for use as an alternative to the Camden which is provisionally named the 'Warren'. It is much cheaper to build than the Camden and should be more tolerant of poor building practices. It has a comparable overall sound insulation to that of the Camden, and its sound insulation curve is much smoother.

Mineral wool in the cavities of the leaves of single or double leaf partitions appreciably increases the sound insulations of the partitions. The sound insulation improves because the mineral wool acoustically treats the cavities.

Adding extra layers of plasterboard to single or double Warrens increases the mean sound insulation by an amount which is approximately equal to the increase that would be expected from considerations of the increase in mass. Adding mineral wool to these increased mass partitions had only a small effect on their sound insulations.

Index terms: *Sound; sound insulation*

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1. INTRODUCTION

1.1 The Camden

There is a common requirement within the BBC for lightweight partitions for separating studio areas. They are often needed because the maximum floor loading figures of the buildings into which the studios are to be built do not allow heavy brick or blockwork walls to be used. A lightweight partition that is used in premises throughout the BBC is the 'Camden' — so named because it was developed for use in the Camden Theatre in the 1940s.

A cross-section through a triple Camden (i.e. having three separate, independently supported Camden leaves) is shown in Fig. 1. Double Camdens and single Camdens are also used extensively, and practical aspects of the use of the Camden in studio environments are discussed in the Guide to Acoustic Practice¹.

The Camden design has many merits which explains why it has not yet been superseded. It is lightweight for the level of sound insulation it provides, and so allows savings in the cost of the building carcass into which studios are to be built.

Studios with heavy masonry walls require strong, massive floors; consequently, the structure of the building carcass has to be considerably stronger. The Camden is also easier to remove than masonry walls, and less disruption is caused to other users of the building when studio areas are refurbished.

The Camden design does have some drawbacks. Camdens are very costly in terms of the time required for construction. The infill squares of fibreboard and plasterboard which are secured to the 25 mm × 25 mm battens have to be individually cut to size, and any gaps have to be sealed with mastic. Although the mid and high frequency sound insulations provided by the Camden are high, the low mass of the partition does result in relatively low sound insulations at frequencies up to 100 Hz. The application of Camden partitions is limited to those situations where this is acceptable. The design also allows much scope for errors and omissions in construction.

1.2 Intended scope of the studies

The aim of these studies was to design metal-framed alternatives to the timber-framed Camden, with a lower cost and construction time, whilst

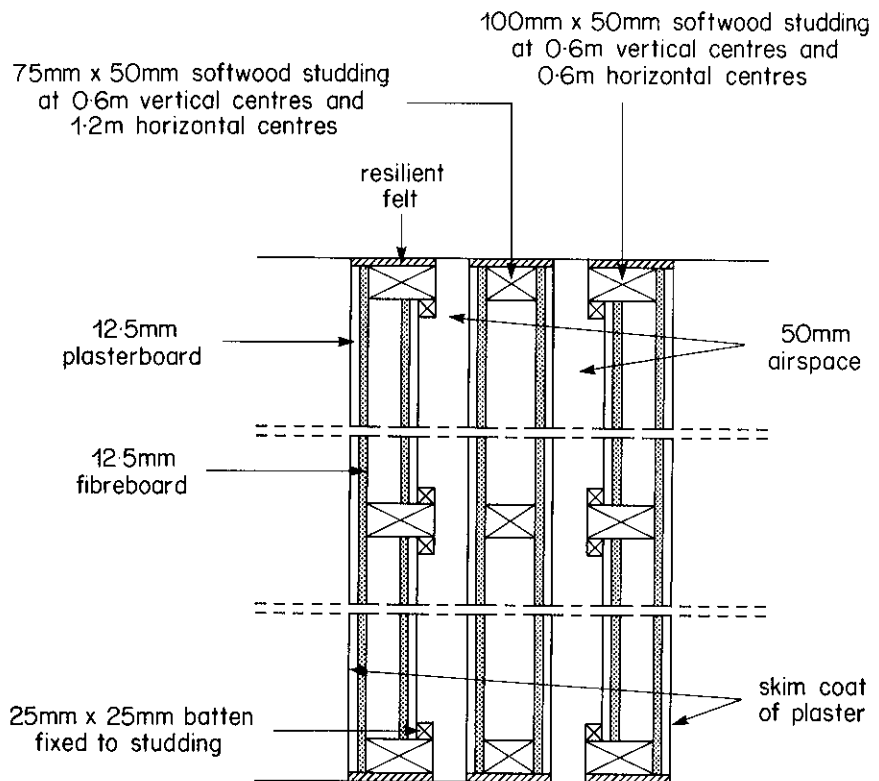


Fig. 1 - Section through a triple Camden.

maintaining a comparable sound insulation. A weight saving might be desirable, although this could probably only be made by accepting a reduced sound insulation. A reduction in partition width would also be desirable, although this would probably result in a reduced sound insulation and a higher fundamental partition resonance frequency. Future studies will include ways of reducing the partition width without compromising the sound insulation (such as by the use of mineral wool in the cavities of the leaves of the partitions).

The BBC Transmission Suite² was used to measure the sound insulations of the partitions in a controlled laboratory environment. The metal studs for the partitions were selected from a range of commercially available studs³. These studies followed on from a detailed investigation⁴ into the behaviour and contributions of the different elements of the existing Camden design*.

Because of their proven history and high sound insulation for their weight, the intention was that the new partitions should be based on double and triple leaf partitions (with independent leaves) using plaster-board damped with fibreboard. Double and triple leaf partitions are also particularly suited to 'box-within-box' (floated room) constructions which provide good isolation from structure-borne sound.

Furthermore, the metal-framed leaves should have the same overall thickness as the leaves in the Camden. As already explained, reducing the stud width would probably compromise the sound insulation, but it would also reduce the rigidity and structural strength of the partitions. Increasing the stud width further would not appreciably affect the low frequency sound insulation of the partition, although it should increase its high frequency sound insulation.

* The theory relating to sound insulation and the definition of the parameters used is given in the companion Report⁴.

However the high frequency sound insulation of double and triple Camdens is more than adequate, and so wider studs are inadvisable because of the consequent reduction in studio area.

Two of the partitions described later are metal-framed versions of the single and double Camden. These have provisionally been named the single Warren and the double Warren. A cross-section through a double Warren is shown in Fig. 2.

Several manufacturers supply modular partitioning systems which generally consist of prefabricated units one leaf in thickness which slot together with acoustic seals at their edges. These systems have comparable sound insulations to similar partitions which are fabricated on site. They are only suitable for use in green-field sites, where modular dimensions can be accommodated in studio designs, and are not normally suitable for refurbishment of existing areas. Most of the partitions described in this Report could be prefabricated as modules, although the difficulties encountered in fitting doors, windows and services would probably make modular units expensive to install and unsuitable for use in BBC studios.

The maximum allowable unsupported heights of the partitions described in this Report are approximately 4 m. However, this height can be increased by the use of cross-bracing or by the boxing of studs. Other practical aspects of partition design, such as maximum permissible structural loading figures and construction costs, are discussed in the Appendix.

2. SINGLE LEAF PARTITIONS

2.1 CS70/R single

A metal-framed equivalent (the 'Warren') of the single Camden was constructed in the opening in the receive room walls of the Transmission Suite,

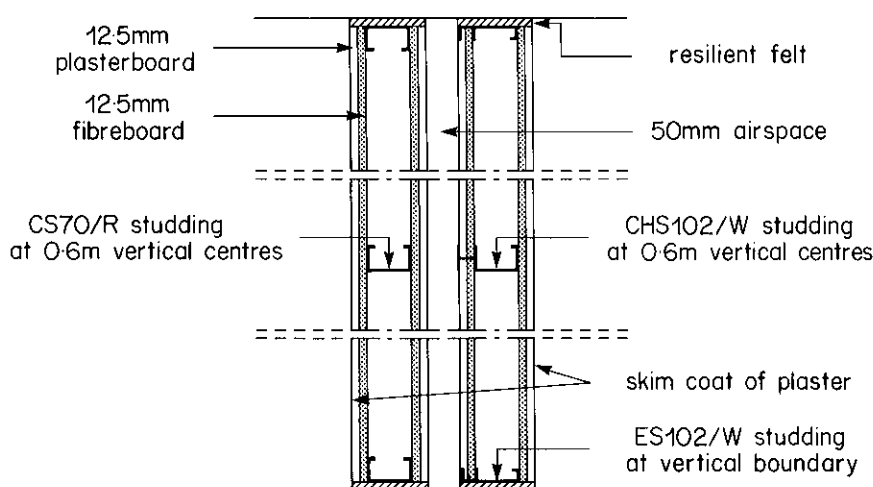


Fig. 2 - Horizontal section through a double Warren.

using Redland CS70/R metal studs on 0.6 m vertical centres. Fig. 3(b) shows the isolation of the single Warren compared with that of a single Camden as measured in the Transmission Suite (Fig. 3(a)).

The sound insulations of the single Warren are significantly higher than those of the single Camden except at 160 Hz and below 125 Hz. The coincidence dip^{5a} at 3.15 kHz is less pronounced for the single Warren. The single Warren has a higher isolation than the single Camden probably because the metal frame bridges the cavity in the leaf less than the timber frame does. The single Warren uses less stud length per unit surface area of the partition and the metal studs are more flexible than timber studs.

2.2 CS70/B single

The first metal-framed single leaf partition had been constructed from CS70/R studs rather than CS70/B studs. The only difference between the studs is that the CS70/R studs are made from 0.55 mm thick steel whereas the CS70/B studs are made from 0.7 mm thick steel. To discover whether the gauge of the steel affected the sound insulation of the partition,

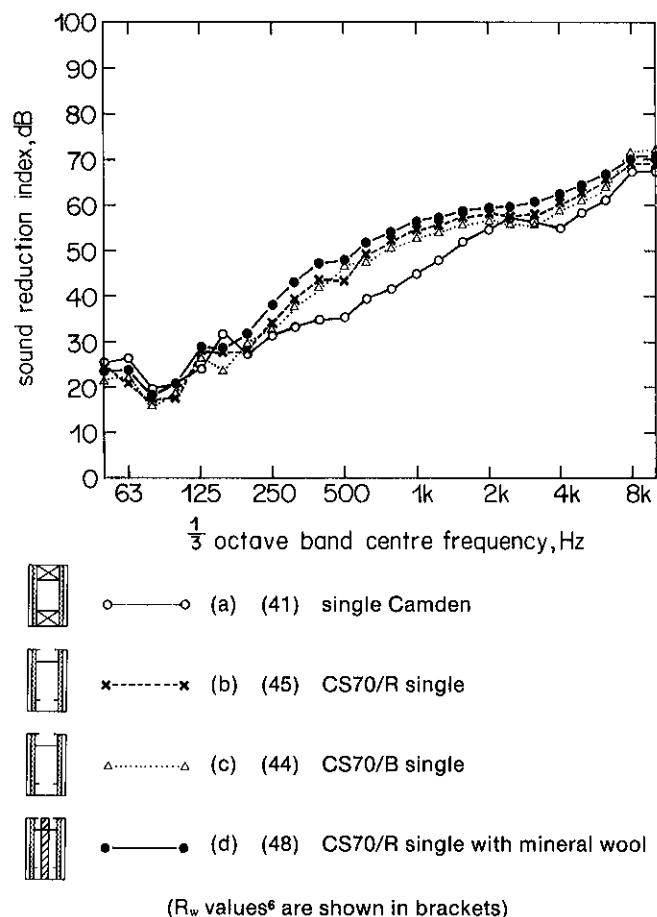


Fig. 3 - The sound insulations of metal-framed, single-leaf partitions.

another single Camden was constructed, this time using CS70/B studs. The measured sound insulation curve of this partition is shown in Fig. 3(c).

There is only a small difference between the sound insulation curve for the partition using the CS70/R studs and that for the partition using the CS70/B studs. The CS70/B-framed partition has a dip in its sound insulation curve at 160 Hz, whereas the CS70/R partition has a dip in its sound insulation curve at 500 Hz. These dips are probably caused by slightly different resonances as a result of the different stud bending stiffnesses. The differences are not significant and acoustically the studs could be used interchangeably. Incidentally, these two measurements indicate the degree of repeatability in sound insulation measurements, including variations arising from the repeated construction of the same type of partition.

2.3 CS70/R single with mineral wool

The sound insulation was measured of a CS70/R, single Warren with mineral wool in the cavity of the leaf to discover whether the mineral wool improved the sound insulation as much as it had for the single Camden⁴. The results are shown in Fig. 3(d).

The mineral wool improved the sound insulation of the single Warren by approximately 3 dB at most frequencies, although the improvement below 200 Hz was erratic. The sound insulation of a single Camden had been observed to increase by 3 dB at most frequencies when mineral wool was used in the cavity of its leaf. The sound insulation is improved because of the additional acoustic absorption provided by the mineral wool in the cavity.

2.4 CS70/B single with two extra plasterboard layers

Another way of increasing the sound insulation of a single-leaf partition is to increase its mass by adding extra layers of plasterboard. Adding two extra layers of plasterboard has been shown to increase the sound insulations of a single Camden by 3 dB at most frequencies. The sound insulation curve of a single Warren with two extra layers of plasterboard is shown in Fig. 4(b).

Adding the two extra layers of plasterboard increases the mean sound insulation by 3 dB which is approximately equal to the increase that would be expected from the mass law^{5b}. However, the increase in sound insulation at different frequencies is much less regular than that for the single Camden, being much higher at frequencies below 630 Hz. The reason for the increase in low frequency isolation being

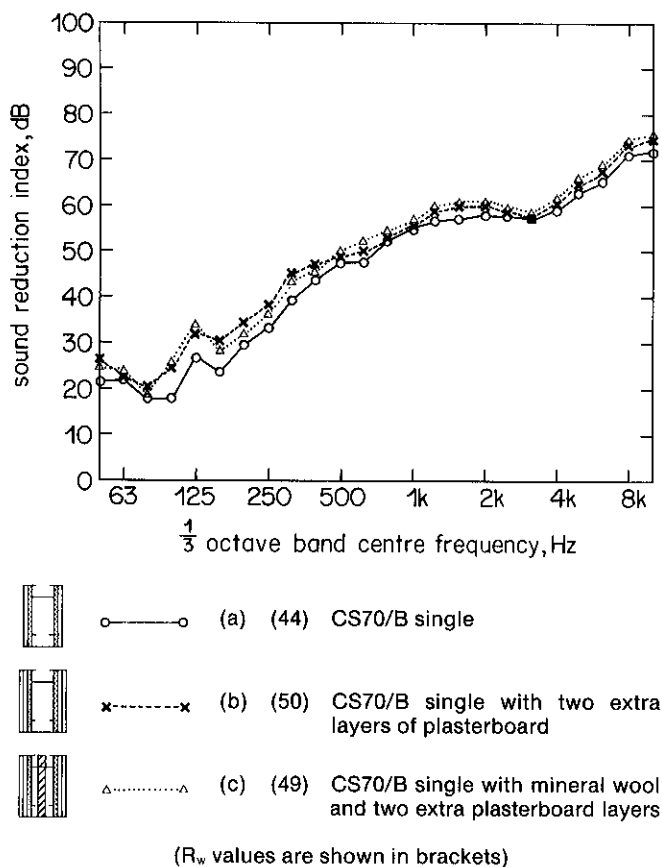


Fig. 4 - The sound insulations of metal-framed, single leaf partitions.

higher for the metal-framed partition is unknown, although it could be that the extra mass of the plasterboard has a greater effect on the resonances in the metal-framed partition because the frame is less rigid (i.e. resonance effects dominate over mass law effects). Adding the two extra layers of plasterboard makes the coincidence dip at 3.15 kHz more pronounced because the fibreboard has a relatively less damping effect. The overall effect on the sound insulation of a single Warren of adding two extra layers of plasterboard is much the same as that of using mineral wool in the cavity of the leaf of a single Warren.

2.5 CS70/B single with mineral wool and two extra plasterboard layers

A 30 mm thick layer of mineral wool was added to the cavity of the leaf of the single Warren, with two extra layers of plasterboard, to determine whether the sound insulation could be further increased. The results are shown in Fig. 4(c).

As with previous measurements on timber-framed partitions, adding the mineral wool did not greatly affect the sound insulations. The mineral wool probably has less effect when there are two extra

layers of plasterboard because the extra plasterboard decreases the proportion of the sound that is carried by the air of the cavity of the leaf (airborne) rather than by the studding (structure-borne) and so the acoustic treatment of the cavity is less important.

2.6 Conclusions from the single leaf partition tests

The sound insulations of the metal-framed partitions are significantly higher than those of their timber-framed equivalents. The metal-framed partition probably has a higher isolation than the timber-framed partition because the metal frame bridges the cavity in the leaf less than the timber frame does. The gauge of the metal stud used does not greatly affect the sound insulation of the partition.

The mineral wool improved the sound insulation of the single Warren by approximately 3 dB. Mineral wool in the cavity of a lightweight single-leaf partition is one way of increasing its overall sound insulation at a moderate cost.

Adding two extra layers of plasterboard to the single Warren increased the mean sound insulation by 3 dB which is approximately equal to the increase that would be expected from the mass law. Adding mineral wool to this increased mass partition does not greatly affect its sound insulation.

3. DOUBLE LEAF PARTITIONS

When constructing double leaf partitions, the first leaf was constructed in the receive room walls, and the second leaf was constructed in the source room walls. Thus the two leaves were mechanically independent which simulates the way in which they would usually be constructed for use in BBC studios. In all cases, the second leaf utilised a Redland Plasterboard steel channel (called Shaftwall), which allows construction of the leaf from one side only.

3.1 CS70/R and CHS102/W double with coreboard

A double leaf partition was tested which was the metal-framed equivalent of the double Camden, except that 25 mm thick Redland coreboard was used as the infill strips in the Shaftwall leaf in place of the inner combined leaf of plasterboard and fibreboard. Use of coreboard facilitates rapid partition assembly. The results are shown in Fig. 5(b) compared with the results for a double Camden, Fig. 5(a).

The R_w value⁶ for the metal-framed partition is 2 dB lower than for the double Camden. The isolation

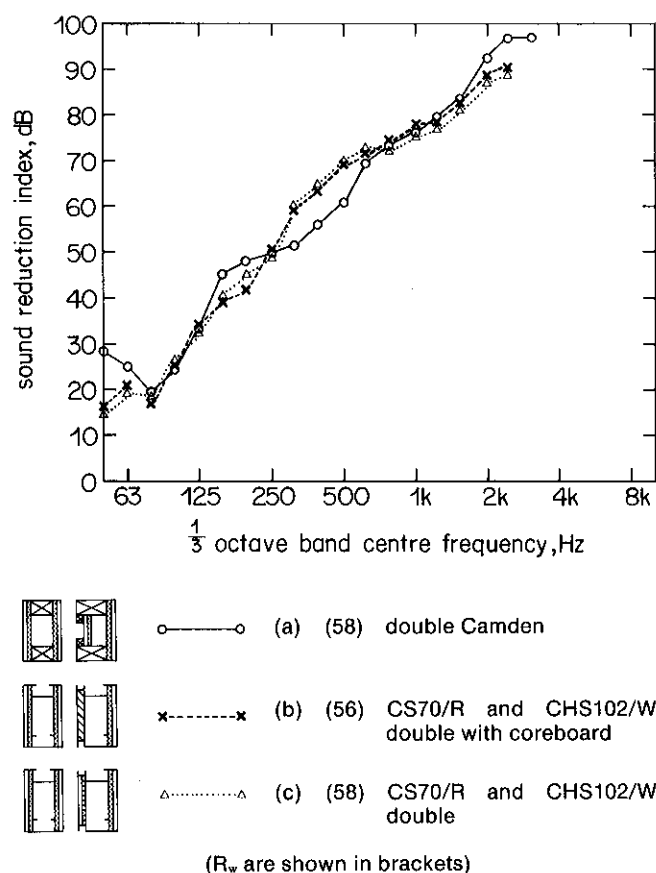


Fig. 5 - The sound insulations of metal-framed, double leaf partitions.

curve of the metal-framed partition is much smoother than that of the double Camden, although it dips below that of the double Camden at 160 Hz and 200 Hz. The metal-framed partition has a higher isolation between 315 Hz and 1 kHz. The performance of this metal-framed partition in relation to the criteria for the sound insulations⁷ of studios is marginally lower than that of the double Camden.

3.2 CS70/R and CHS102/W double

Because the metal-framed partition using coreboard had a marginally lower sound insulation than that of the double Camden, the coreboard was replaced by 600 mm wide strips of plasterboard taped to 600 mm wide strips of fibreboard to make the partition more closely resemble a double Camden. This makes the construction process slightly more time-consuming, but the overall increase in construction cost would be minimal. The results of the sound insulation measurements are shown in Fig. 5(c).

The R_w value for the double Warren is the same as that of the double Camden. The isolation curve of the metal-framed partition is much smoother than that of the double Camden, although it dips below that of the double Camden at 160 Hz and

200 Hz. The metal-framed partition has a much higher isolation between 315 Hz and 600 Hz. The performance of this metal-framed partition is generally comparable with that of the double Camden, so it would be satisfactory as a replacement.

3.3 CS70/R and CHS102/W double with mineral wool

When using mineral wool in the cavities of single leaf partitions, overall increases in the sound insulations of approximately 3 dB have been observed. In previous studies of the sound insulations of timber-framed partitions, the effects of mineral wool in the cavities in the leaves of a double Camden on its sound insulation had not been investigated. The effects of mineral wool in the cavities of a double Warren on its sound insulation were therefore measured. The results are shown in Fig. 6(c) compared with the results for a double Camden, and the same metal-framed partition without mineral wool, Fig. 6(b).

Adding the mineral wool to both cavities in the leaves of the double Warren increased its R_w value

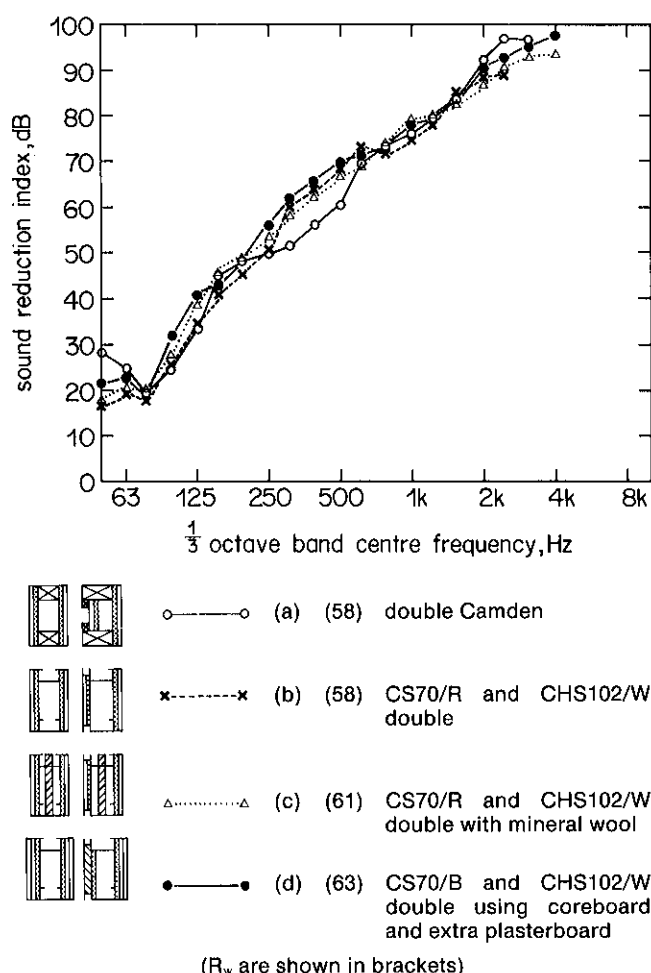


Fig. 6 - The sound insulations of metal-framed, double leaf partitions.

by 3 dB although the mean isolation* increases by only about 1 dB. The increase in isolation only occurs at frequencies up to 400 Hz but this increase is valuable as the high frequency isolation of double Camdens is already higher than required in most situations. The increase in isolation obtained must, however, be offset against a marginal increased construction cost.

3.4 CS70/B and CHS102/W double with extra plasterboard

When doubling the number of plasterboard layers in single leaf partitions, overall increases in the sound insulations of approximately 3 dB have been observed. The effects of adding extra layers of plasterboard to a metal-framed double leaf partition on its sound insulation were measured. The results are shown in Fig. 6(d) (note that the partition is not an exact representation of a double Warren with four extra layers of plasterboard, as one of the double layers of plasterboard has been replaced with a layer of coreboard, which has an equal density to plasterboard, for ease of construction).

Adding the extra plasterboard increased the mean isolation by approximately 3 dB, as would be expected from the mass law. However, the R_w value increased by 5 dB because most of the increase in insulation occurred below 630 Hz. In situations where higher floor loadings and extra construction costs are less important, this type of partition could be used to provide a higher degree of sound insulation.

3.5 Alternative design for a double leaf partition

At an earlier date, an alternative partition to the double 'Warren' had been tested independently in another Transmission Suite. As a 'reproducibility test'⁶, the sound reduction indices of this alternative partition design were measured in the BBC Transmission Suite. Fig. 7 shows the sound reduction indices of the alternative partition design as measured at the BBC together with the sound insulation curve of the double Warren for reference. The key to Fig. 7(b) shows the construction details of the partition. There are two Shaftwall leaves which are back-to-back. These Shaftwall leaves are similar to that in the double Warren (Section 3.2), except that the plasterboard and fibreboard layers have been reversed on the inner side of each leaf.

The alternative design of partition (Fig. 7(b)) had an R_w value 2 dB higher than that of the double Warren (Fig. 7(a)). The sound reduction indices of the alternative partition design are higher above 400 Hz

* The definition of the parameters used is given in the companion Report⁴.

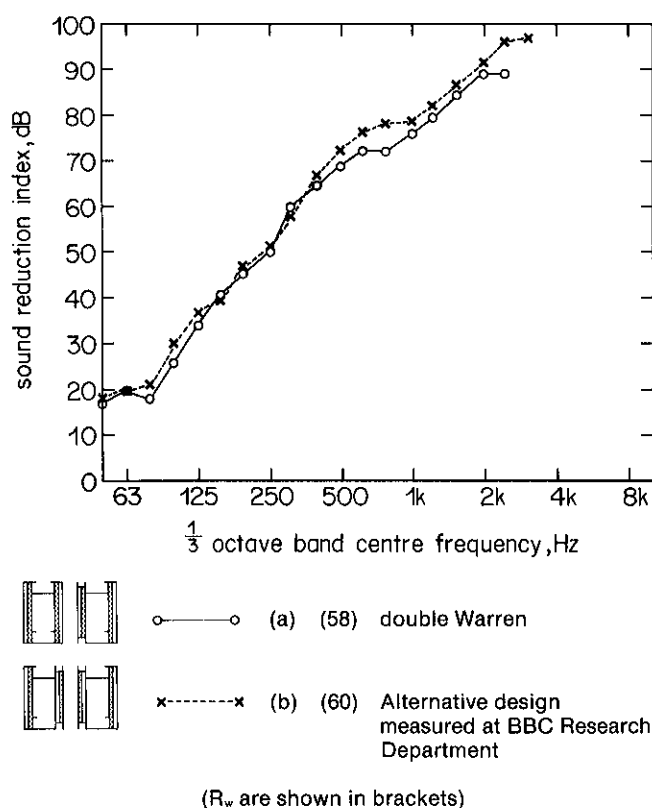


Fig. 7 - The sound insulations of metal-framed, double leaf partitions.

(the reliability of values below 125 Hz is suspect). The isolations are probably higher for the alternative partition design because the fibreboard is distributed throughout the three cavities of the partition, rather than just two, as in the double Warren. Thus, the acoustic treatment is distributed throughout the partition, so it will have a greater overall effect. The replacement of the standard metal studs, with the Shaftwall studs, was probably not responsible for the increase in isolation. It is probably inadvisable to construct studio partitions in the same way as this alternative partition, because the cavity between the two leaves might have a lower fire integrity. However, these results do suggest that the addition of further acoustic treatment (such as mineral wool) to the cavity, between the two leaves of the double Warren, would increase its sound insulation; this matter may be the subject of further studies.

3.6 Effects of loading

It had been suggested that loading metal-framed partitions with standard BBC modular acoustic treatment might degrade the sound insulation performance by disturbing the resonances in the partition. The effects on the sound insulation of the alternative partition (Section 3.5), of mounting 24 type A3 modular absorbers on either side of the partition, are shown in Fig. 8.

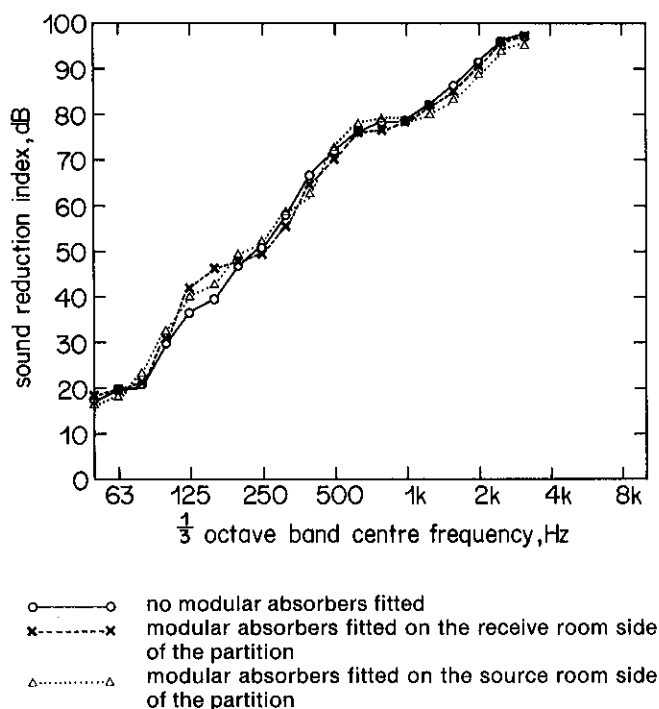


Fig. 8 - The effects of A3 modular absorbers on the SRI of the alternative partition design.

Adding the modular boxes to the partition had only a small effect, apart from slightly increasing the sound insulations at 125 Hz and 160 Hz. These increases are probably caused by additional sound being absorbed as it passes through the modular boxes, although they could also have been caused by a disturbance of the panel resonances of the partition or as a result of the extra mass. As expected from reciprocity considerations, the side of the partition to which the modular boxes were fitted did not have an appreciable effect on the measured sound insulations. Thus, fitting modular acoustic treatment to metal-framed studio walls should not impair their performance.

3.7 Conclusions from the double leaf partition tests

The performance of the metal-framed double leaf partition using coreboard was generally slightly lower than that of the double Camden. The performance of the double Warren was generally comparable with that of the double Camden, and so it would be satisfactory as a replacement.

The sound insulation performance of the single Warren was higher than that of the single Camden, whereas the performance of the double Warren was only comparable with that of the double Camden. The reason for this discrepancy is not known. However subsequent measurements have suggested that the Shaftwall leaf may have suffered from leakage at its

top and bottom. This is because the wide infill boards were not sealed with acoustic sealant to the top and bottom boundary tracks (as is usual practice), and because the infill boards were less than the full height of the partition. The sound insulations of the double leaf partitions might have been higher had these defects not occurred. In future, the infill boards should be cut so that they are the full height of the partition.

Adding the mineral wool to the double Warren increased its mean isolation by about 1 dB, but the increase at low frequencies was higher. The increase in isolation obtained must be offset against the marginally higher construction cost.

Adding extra plasterboard increased the mean isolation of the metal-framed double leaf partition by approximately 3 dB as would be expected from the mass law, and most of the increase in insulation occurred at lower frequencies. In situations where the higher floor loadings and extra construction costs can be tolerated, this type of partition could be used to provide a higher degree of sound insulation.

The alternative design for a double leaf partition had a higher insulation than the double Warren, although the fire integrity of the alternative partition may be deemed to be insufficient for use in studio environments. Securing modular boxes to this alternative partition did not greatly affect its sound insulation. Thus fitting modular acoustic treatment to metal-framed studio walls of a similar construction should not impair their performance.

4. OVERALL DISCUSSION

The sound insulations of metal-framed equivalents of the single and double Camdens have been measured. A metal-framed equivalent of the triple Camden could be constructed by using another Shaftwall leaf, as shown in Fig. 9. Practical construction difficulties prevented a triple Warren from being tested in the Transmission Suite. However, a triple Warren probably would have a sound insulation that was comparable to, or higher than that of the triple Camden (provided the tops and bottoms of the Shaftwall leaves have been properly sealed).

Adding mineral wool inside the leaves of the single and double Warrens improved their sound insulations. Adding mineral wool inside the leaves of a triple Warren would probably also improve its sound insulation. Adding mineral wool between the leaves of the double and triple Warrens would probably increase the sound insulations further. This should have a greater relative effect than treating inside the leaves, as there would otherwise be no acoustic

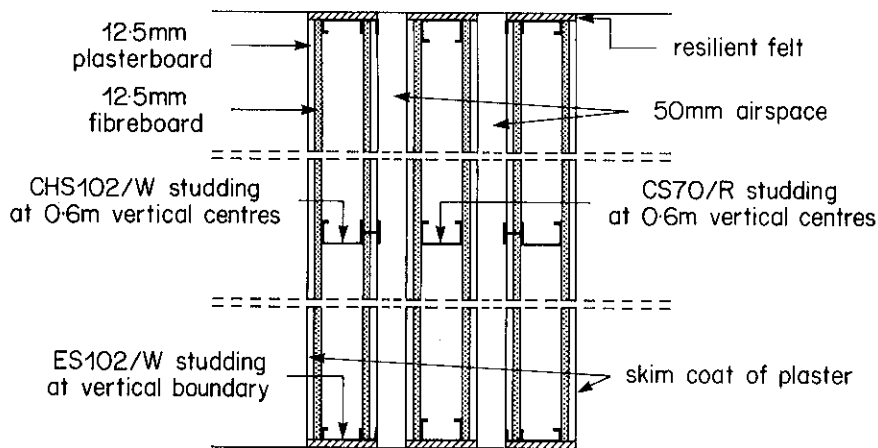


Fig. 9 - Horizontal section through a triple Warren.

treatment in the cavity between the leaves (there is already fibreboard inside the leaves which is more absorbent than plasterboard).

5. CONCLUSIONS

New partition designs have been tested which are essentially the same as single and double Camdens, except that the timber studs have been replaced by proprietary metal studs. The metal-framed partitions are provisionally named single and double Warrens. These new partitions should be much cheaper to build than their timber-framed equivalents, and should also be more tolerant of poor building practices. It is envisaged that the designs could be extended to a triple leaf partition, with a comparable sound insulation performance to that of the triple Camden. As part of the studies, a range of metal-framed partitions with varying masses, costs and sound insulations have been designed and tested so that an appropriate partition can be selected for use in a particular studio environment.

The sound insulations of the single leaf, metal-framed partitions are higher than those of their timber-framed equivalents. The single Warren probably has a higher sound insulation than the single Camden because the metal studs provide more of a vibration break than the timber studs in the cavity of the leaf. The sound insulation of the partition is not significantly affected by the gauge of the stud metal.

The sound insulation of the double Warren is comparable with that of the double Camden. Other measurements have indicated that there may have been leakage at the top and bottom of the Shaftwall leaf. In future, the infill boards should be cut so that they are the full height of the partition. For structural strength, the vertical steel channels must be cut so that they are a tight fit in the top and bottom boundary tracks and should be secured to the tracks with screws.

Mineral wool in the cavities of the leaves of

single or double leaf partitions appreciably increases the sound insulations of the partitions. The sound insulation is improved because of the additional acoustic absorption provided by the mineral wool in the cavities. The marginal increase in construction cost on using mineral wool, in the leaf cavities of a lightweight partition, is probably justifiable because of the resultant increase in overall sound insulation.

Adding extra layers of plasterboard to Warrens increases the mean sound insulations by an amount that would be expected from the mass law. Adding mineral wool to these increased mass partitions does not greatly improve the sound insulations.

6. RECOMMENDATIONS

This Report has described the construction and testing, under laboratory conditions, of metal-framed equivalents for an existing series of lightweight partitions. Some practical problems remain to be solved; for example, the architectural detailing of corners, the fitting of doors and windows (especially the very heavy types used in studio construction), and other building site considerations. As a field trial, it is proposed that some test constructions will be built in a real studio environment, preferably on a less critical project. Such field trials should also yield accurate data on construction costs and timescales.

A good comparison of the performance of the Warren with that of the Camden could be obtained by building two identical studio areas, one using Camdens and the other using Warrens. Comparison of the corresponding isolations in both areas would then show up any weaknesses in the new partition design compared to that of the Camden. Also triple leaf versions of the partition design should be tested to ensure that a similar performance to that of the conventional triple Camden is achieved. It is unlikely, however, that such exact comparisons will be made, because of financial constraints.

7. ACKNOWLEDGEMENTS

The assistance of Redland Plasterboard in supplying the materials and for constructing the partitions is gratefully acknowledged.

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APPENDIX

Practical Aspects

As part of the design process, it was necessary to consider the load-bearing capabilities of the metal-framed partitions. For a typical talks studio at Bush House (7th floor centre block — continuity suite CON1B), the total load per column that must be carried by the studs is 0.67 kN.

Calculations have shown the load capacity, per stud, of the CS70/B studs to be 15.3 kN and the load capacity, per stud, of the Shaftwall (CHS102/W) studs to be 61.5 kN. Generally, the majority of the ceiling loads in a studio would be carried by the Shaftwall studs. It can be seen that the partitions will easily be able to support the expected loads.

It is difficult to obtain precise, comparable figures for construction costs of the Warren and the Camden. Redland Plasterboard figures for the materials costs are £6.83/m² for the single Warren and £11.79/m² for the double Warren. The labour cost for their construction is approximately the same as the materials cost per square metre of partition. One recent figure for the combined materials and labour costs of constructing a single Camden is £37/m² (others have been significantly higher than that). Assuming the materials costs are similar to, but slightly less than those of the single Warren, then the labour costs of constructing a single Camden are approximately five times larger than those of a single Warren. As additional verification, using experienced fabricators, the construction time of 12 m² of single Warren in the Transmission Suite was one day, whereas for the same area of single Camden it was five days. These figures give an indication of the magnitude of the savings that might be made by using Warrens.